Top Search in Lepton + Jets with SecVtx b-Tagging

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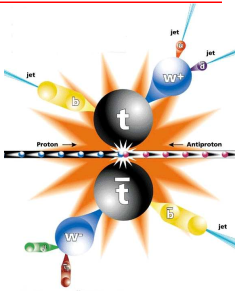
Original figures presented by me at the CDF collaboration meeting on 1/21/1995 when we decided we discovered the top quark. These results are published in the top discovery PRL.

EXECUTIVE SUMMARY

We report on the top search using the SecVtx seed-vertexing algorithm in the lepton + jets data sample. Combining run1A(19 pb^{-1}) and run1B(48 pb^{-1}) lepton + 3 or more jets samples, we find 27 tags with an expected background of 6.7 ± 2.1 tags. The probability that the observed yield is consistent with a fluctuation in background is estimated to be $\approx 2.0 \times 10^{-5}$ ($4\,\sigma$). The kinematic distribution of b-tagged events are found to be consistent with the amount of top plus background in the sample.

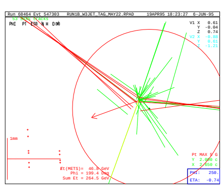
Top Quark Production at Tevatron

At the Tevatron, the top quark is produced singly and predominantly in pairs and decay almost exclusively to $W+b$, resulting in a $W^+W^-b\bar{b}$ state. Further combinations of W decays to electrons, muons, and jets result in final state fractions of 5%, 30%, and 44% for the dilepton, lepton+jets, and fully hadronic signatures, respectively. The analysis we present here uses the lepton + jets channel, which has 30% of top pair branching ratio and large background from higher-order production of W bosons.



Search Strategies and Data Sample

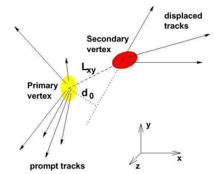
We look for events where one of the W bosons has decayed into an electron (or muon) and 3 or more jets. In order to enhance the signal to backgrounds ratio, we exploit the lifetime of the b quark that can produce a secondary vertex up to several millimeters away from the collision point. Most of the non-$t\bar{t}$ processes found in the W+jets sample do not contain heavy flavor quarks in the final state. By requiring a jet to be "b-tagged" using the tracking precision of the CDF Silicon Detector, we can keep about 40% of the top quark events while removing 90% of the background events.



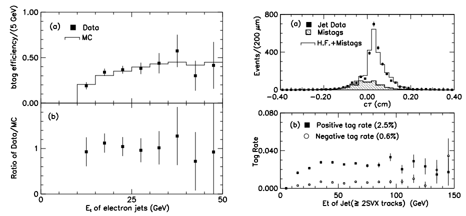
The data sample used for this analysis consist of 67 pb^{-1} of data collected with the Collider Detector at Fermilab (CDF) at $\sqrt{s}$=1.8 TeV during 1992-1995 period.

A Seed-Vertexing Algorithm for Top

Secondary vertices are reconstructed by selecting tracks within the jet that have a large impact parameter and satisfy some tracking quality requirements. In a first pass, the algorithm attempts to reconstruct vertices with at least 3 tracks. If none is found, it tries to reconstruct 2 track vertices with more stringent cuts on the track selection. A jet is b-tagged if a secondary vertex is reconstructed with a significant decay length in the transverse plane (L_{xy}).



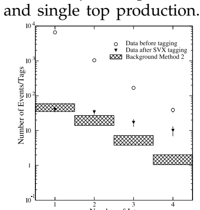
- The performance of SecVtx is measured using generic jets and inclusive lepton samples and b-tagging efficiency is determined to be 25± 5 % greater than that of previous tagger while the mistag rates are comparable.
- The efficiency is measured separately in the data and in the Monte Carlo using an enriched $b \rightarrow e\nu X$ sample. The ratio of efficiencies between data and simulation is then used to correct for the b-tagging efficiency in $t\bar{t}$ Monte Carlo samples, which found that the efficiency to tag at least one bjet in a $t\bar{t}$ event is $\epsilon_{tag} = 42 \pm 5\%$.
- The mistag rates ($L_{xy} < 0$) are determined directly from inclusive generic jet data. The average mistag rate per taggable jet is about 0.5%.



Event Counts after b-Tagging

The dominant backgrounds to the $t\bar{t}$ signal in the b-tagged W+jets sample include contributions from heavy flavor physics events ($Wb\bar{b}$, $Wc\bar{c}$, Wc), b-mistags ($Wq\bar{q}$), and fake non-W leptons in QCD jet sample. A smaller contribution comes from Z+jets, di-bosons and single top production.

Background are estimated as a function of jet multiplicity. The background estimated in the 1-jet and 2-jet bins are a good check of the method because the $t\bar{t}$ signal contribution in these bins are small. The plot below shows the sum of all background contributions, compared to the data. **In the W + 3 or more jets sample, we find 27 tags with an expected background of 6.7 ± 2.1 tags. The probability that the observed yield is consistent with a fluctuation in background is estimated to be $\approx 2.0 \times 10^{-5}$, which is equivalent to a 4.0 σ effect.**



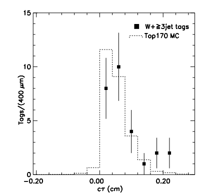
Checks on the Z + Jets

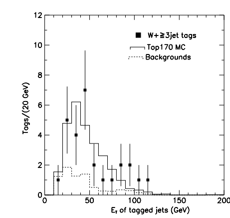
The Z+jets sample is used as a cross-check of our understanding of the heavy flavor content since the $t\bar{t}$ and non-W QCD contamination in these samples is small. The table below lists the yield of Z candidates and the number of b-tagged events observed as a function of jet multiplicity. The background predictions are also given and are calculated in the same way as for the W+jets sample: $7.8 + -1.1$ events are predicted and 7 events are observed.

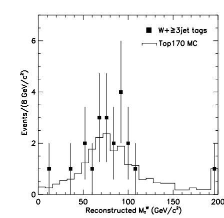
Z+Njet	1jet	2jet	$\geq$ 3jet
Backgrounds	5.6 ± 0.8	1.5 ± 0.2	0.7 ± 0.1
Data	3	3	1

Kinematic Distributions

The properties of the selected candidate events are consistent with the expectation for $t\bar{t}$ pair production and background contributions. The following plots show the pseudo-$c\tau$ of the tagged events, the b-tagged jet E_T, and the W transverse mass.







$t\bar{t}$ Production Cross Section

The $t\bar{t}$ production cross section is obtained from the acceptance measurement and the excess of events over the background estimate:

$$\sigma_{t\bar{t}} = \frac{N_{obs} - N_{bkg}}{\epsilon_{t\bar{t}} \times L} = 6.8^{+3.6}_{-2.4}(\text{pb}),$$

from the lepton +jets channel with SecVtx b-tagging for a top quark mass $m_t = 175$ GeV/c^2.